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ABSTRACT

This working paper presents an analysis that seeks to refocus thinking about the question of educational resources needed for transformation in schools. Both the context of science education and the teaching practices of science teachers as potential resources that can be marshaled to facilitate the transformation of science education in schools are presented. Context resources and practice resources are identified as crucial to the success of educational transformation, and this study is concerned with a microanalysis of these resources. The results of the research suggest that a great deal of potential for school change exists in teachers' knowledge, time available, human and textual resources, and various teaching practices that feature a transformative engagement. Contains 33 references. (DDR)

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RESOURCES FOR TRANSFORMING SCIENCE EDUCATION

The Context and Practice of High School Science Teaching

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INTRODUCTION

In the three years after its inauguration, the new government of South Africa made significant gains in its attempts to dismantle the surviving pillars of apartheid education. At the top of the list were issues of governance and management at national, provincial and local levels, as the government sought to unify the different sub-systems created by the apartheid policies.

Recently, however, focus has shifted to other aspects of education. Transformation of teaching and learning in schools is high on the government's agenda, including the transformation of science education. The development of the new curriculum, with its focus on student-centered learning, coupled with the special focus on science and technology through initiatives such as Students and Youth into Science, Technology, Engineering and Mathematics (SYSTEM), began to advance the discourse of transformation in schools.

Although fairly well thought out, the success of these recent initiatives to change classroom practices (of teaching and learning) is not guaranteed. Complaints about inadequate consultation with, and involvement of teachers in the processes and the acute shortage of resources, are two important reasons to be sceptical. The latter has received much attention recently with the much publicised *School register of needs survey* (DoE, 1997c) that details the inhospitable physical conditions of some of the disadvantaged schools in the country.

The disappointing pass rates of grade twelve candidates in 1997 (and high failure rates in most provinces) have again focused attention on the resource question. Also, the impending termination of contracts for temporary teachers, school cleaners and security personnel highlights the problem of shrinking resources for the continued transformation of education in schools.

Despite increased attention to the problem, educational resources are not likely to increase in any significant way in the foreseeable future. Already, as a percentage of the country's Gross Domestic Product (GDP), South Africa is spending 6½% on education, way above most countries, both developed and developing. A new way of thinking about the utilisation of educational resources for transformation is needed.

This working paper presents an analysis that seeks to refocus thinking around the question of educational resources needed for transformation in schools, in which a much broader definition of the concept of 'resources' is considered. The paper presents both the ***context of science education*** and the ***teaching practices of science teachers*** as (potential) resources that can be marshalled to facilitate the transformation of science education in schools. While it is acknowledged that physical and material needs are important, recent research in countries where physical and material needs are less of a problem, seems to suggest that there are other kinds of resources equally crucial to the success of educational transformation (see Cohen and Ball, 1996; Floden et al, 1995; Price et al, 1995; Jennings and Spillane, 1997). We group these 'other' resources into two categories:

i. Context resources

ii. Practice resources

This study is concerned with a micro-analysis of these two kinds of resources.

Although more research is needed to clarify the optimal balance between the two categories of resources in the various teaching situations, they are regarded as being mutually complimentary and, to a limited extent, compensatory. For example, in disadvantaged schools where teachers participate actively in the curriculum reform processes, they develop superior knowledge of the reform agenda and

simultaneously use their time to meet and discuss new ideas. Also, parents who actively support high quality teaching and learning at such schools, enable teachers to channel their energy into coping with poor material conditions.

In disadvantaged schools where teachers have fewer opportunities to implement the ideas of transformation, less time to learn and reflect, fewer textual materials to draw on, and a weaker grounding in pedagogical approaches that encourage student participation in the learning processes, the problem of trying to offer high quality instruction is compounded.

Conversely, historically advantaged schools with built in opportunities for teacher reflection and discussion, located in environments with an abundance of textual resources for teaching and learning, and where pedagogies that encourage student participation and responsibility are both appreciated and developed, have a head start in the process of educational transformation. Teachers in such schools need only to grapple with the new ideas of transformation and organise time to learn and share with other teachers. This Working Paper assesses these, and other assumptions about the balance of the two kinds of resources in a number of public schools in South Africa.

Specifically, the research investigates:

1 The current context (as a resource/potential resource) for science teaching and learning in public schools, in terms of:

- Teachers' knowledge (of subject matter, curriculum reforms, science reforms).
- Efficiency and effectiveness of human resource deployment in terms of time utilisation (e.g. deployment of teachers in science classrooms, time available to learn new ideas, etc.).
- Use of textual materials (textbooks, libraries, newspapers etc).

- Human resources and their characteristics (particularly teaching staff), as well as the influence of learners and parents.

2. Current classroom practices (as resources/potential resources) of science teachers in public schools, in terms of:

   - Beliefs about science (and science teaching).
   - Goals and objectives re: content knowledge, that are emphasised.
   - Goals and objectives re: skills that are emphasised.
   - Preferred pedagogical approaches used in the classrooms.

3. Ways in which resources of context and practice can be reshaped for the transformation of science education.

In research studies on curriculum implementation in subjects other than science, Nduna-Watson (1994) and Adler (1991/2) identify constraints and contextual factors that limit the effectiveness of teachers in the classroom. The current research builds on this limited pool and seeks to investigate the *status quo* in science education with a view to understanding how to reshape it in the service of transformation.

Sample Schools

To answer questions about the context and practices of science teaching in some KwaZulu-Natal schools, a survey of 15 secondary schools with a total of 87 science teachers[1] was conducted. Schools were selected on the basis of a consultation with the science advisory office of the Durban South region of the KwaZulu-Natal Department of Education and Culture. A list of 25 schools in the Durban South

[1] In this study, the term 'science teacher' encompasses teachers of biology, physiology, general sciences, physics and chemistry.

and Durban North regions was compiled with science subject advisors in Durban South. The schools in Durban South were selected on the basis of evidence of innovative teaching practices and their potential to co-operate with the researcher. Four schools were selected from Durban North on the basis of proximity to one of the identified Durban South schools.

The granting of permission to conduct research in the Durban South region was slow. In anticipation of further time delays requesting similar clearance from Durban North, it was decided to limit the research to Durban South schools. The remaining 21 schools were contacted and invited to participate in the study. After three weeks soliciting participation, including the offer of an incentive to the science departments of participating schools (based on the number of questionnaires returned), 13 schools committed themselves to the project.

These 13 public schools represented a mix of schools previously administered by diverse departments in the former education system of South Africa. Table 1 provides additional information about the sample schools.

Table 1: Characteristics of the Sample Secondary Schools[2]

Former Administrative Authority	Rural/Small town	Urban	%
DET or KDEC (for African learners)	3	4	47%
HoR (for coloured learners)	1	-	7%
HoD (for Indian learners)	-	2	13%
NED (for white learners)	2	1	33%

Although all school types were represented in the sample, the former NED and HoR urban schools were under-represented because several schools of this type declined to participate in the research. No former HoD school in a rural area of Durban South was identified at the time of selecting the sample.

Although 13 schools agreed to participate, teacher participation remained voluntary throughout and teachers were able to withdraw at any stage of the project – a *proviso* designed to protect the participants against coercion. In total, 87 questionnaires were sent to schools and 54 teachers elected to respond and participate, resulting in a 64% return rate. Two factors improved the return rate significantly:

- Personal delivery and collection of the teacher questionnaires by the researcher.

[2] Although place (i.e. whether a school is urban or rural in location) is often used as an indicator of poverty or provision of facilities and other educational needs, schools in this study did not show any significant variation in this regard. This is partly because all the 'rural' schools were in fact peri-urban (the furthest was less than 50km from Durban) and had reasonable access to the city. For analytical purposes former administrative department proved to be a better characteristic for disaggregating the results.

- The incentive of a book voucher as a financial contribution to the science department of each participating school, based on the number of questionnaires returned.

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by
Loyiso Jita

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Education Policy Unit
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SECTION 1: CONTEXT AS A POTENTIAL RESOURCE FOR SCIENCE TEACHING AND LEARNING

1. Human resources for the transformation of science education

The unit of analysis for this study is the individual science teacher. We sought to characterise science teachers in terms of race, gender, age and experience.

1.1 Race

About 50% of the sample teachers were African, 20% each were Indian and white, while only 7% were coloured. These figures correspond with the school sample characteristics in Table 1. Indeed, the sample was designed to reflect the realities of the education system that emerged after decades of legislated segregation. Accordingly, it was expected that schools formerly for learners of different racial groups would still be staffed largely by teachers from those racial groups. The few exceptions to this pattern occur only in instances where white teachers are deployed to senior positions in schools formerly for other racial groups. Recently, several Indian teachers have also been deployed to African schools. Practices of racially based staffing patterns have continued with very few exceptions, despite the affirmative action policies of the new government. Two reasons for this *status quo* are:

i. Lack of transparency in filling teaching positions in the schools. Until recently, filling of vacancies was the prerogative of provincial departments of education. Historically, departments also delegated this task to school principals who sometimes consulted the chairperson of the school management committee about recruitment from within the staff ranks and the local community.

ii Institutionalised racism discouraged teachers, particularly Africans, from considering positions in schools outside their 'own areas'. This was exacerbated by the fact that the 'inconvenience allowance' offered to white teachers employed outside of white areas was not available to 'non-whites'.

Although the policies of the new government *vis-a-vis* transparency and affirmative action may, in time, act to reverse the situation, institutionalised racism will continue to counterbalance these corrective actions.

1.2 Gender

It is commonly held that women are under-represented in the field of science, especially at tertiary levels (Kahn, 1993). With a female:male ratio of 60:40 in this small sample of teachers, it is not clear whether this under-representation also holds in the field of secondary school science teaching. More research is required to establish whether this ratio is generalisable. An alternative explanation for the higher percentage of female science teachers in the sample might be that biology, physiology and general sciences have been included. These subjects are often overlooked in preference of the 'hard sciences' like physics and chemistry.

1.3 Age and teaching experience

Our findings suggest a relatively young teaching corps. Most of the respondents began teaching in the last 9 years.[1]

[1] Although this may be considered long service by other researchers (for example Maimunah, Zin and Lewin (1993) consider teachers with five years teaching experience as 'experienced'), our conception of veteran teachers in South Africa is calculated to cover the period before the mid-80s when political and educational crises often paralysed effective teaching in schools. Younger teachers who started teaching during the times of crisis inevitably have an uncommon or unusual set of experiences relative to their colleagues elsewhere on the globe.

Table 2: Teaching Experience in Categories

Value Label	Value	Frequency	Percent	Valid Percent	Cum. Percent
No data	-1.00	1	1.8	1.8	1.8
1-3 yrs	1.00	12	21.8	21.8	23.6
4-6 yrs	2.00	8	14.5	14.5	38.2
7-9 yrs	3.00	13	23.6	23.6	61.8
10-14 yrs	4.00	12	21.8	21.8	83.6
15-24 yrs	5.00	9	16.4	16.4	100.0
Total		**55**	**100.0**	**100.0**	

Three out of five respondents (i.e. 60% of the respondents) began teaching in the last nine years. This experience profile of the teachers corresponds to the age profile. About four out of five respondents are under the age of 39 (i.e. 84.4%). The findings regarding the younger and mid-career majority of science teachers are explained in a number of ways:

- **Promotions to senior posts:** One of the paradoxes of the teaching profession is that recognition and promotion of good teachers often takes them out of the classroom and into administrative and management positions. More experienced and senior science teachers may be moving up the ladder within (or out of) the profession.
- **Conversion to other subject areas:** Another finding of this study (to be discussed later) is that science teachers do not only teach science but are also qualified and deployed to teach other subjects. For instance, it is not uncommon to begin one's career as a science teacher and retire as a mathematics teacher. School characteristics, deployment patterns, experiences with subject matter and learners, and interests, shift during the course of the career path.

- **Attrition:** Career changes among science teachers are not uncommon. In fact, science teachers are among the most sought after professionals in other areas of science and technology.

If the findings of this study are generalisable, the absence of veteran and experienced teachers in secondary science classrooms is disturbing. This has major implications for the professional development and mentoring of new teachers. Veteran teachers often possess tacit knowledge generated through years of (reflective) practice that would benefit neophytes in the profession. More importantly, in a situation where so little has been written about the practice of science teaching, veteran teachers are the custodians of the history of the profession. Further (and much broader) research is required to investigate clearly the experience profile of science teachers in South Africa, and if the patterns in this study are confirmed, the reasons for this attrition.

2. Teacher deployment

To understand some of the issues of efficiency and effectiveness in the deployment of human capacity in schools, we examined six indicators of teacher deployment.

2.1 Teachers' position within the school hierarchy

In all the racial groups, about 90% or more of the respondents were post level one teachers. Of the remaining 10% or so, 7% were Heads of Department (HODs) and 2% were Deputy Principals (DPs). Further analysis revealed that three quarters of the HODs were female. Against the background of a tapering hierarchy in the school structure, the small number of science teachers in senior posts is not unexpected. Furthermore, our earlier findings on the relative youthfulness of the teaching corps in the sample may also account for the low percentage of these teachers in senior positions. An important observation, however, is that despite the limited opportunities for professional advancement of science teachers

within the school hierarchy, female teachers occupied three out of four HOD positions in this sample. This surprising finding again begs for a much broader investigation of the role of women teachers in science education in general.

2.2 Nature of appointment

A quarter of the respondents were in temporary appointments, evenly split between males and females. This relatively high number is not entirely unexpected.

From a research perspective, as early as 1992, Soobrayan (1992) reported a figure of about 20% for temporary appointments in his sample of coloured teachers (not specific to science teachers) in greater Durban. Reddy and Khumalo (1997) reported that a third of the science teachers employed by the KwaZulu Department of Education and Culture (KDEC) in 1994 had neither a science credit nor a teaching qualification thus causing their appointments to be temporary.[4]

Furthermore, from a political or popular standpoint, the recent announcements by the provincial department of education of the impending dismissal of about 20 000 temporary teachers in KwaZulu-Natal, later reduced to 5 000, also suggests the presence of large numbers of temporary appointments in the province. All this points to a rather uncertain professional path for most science teachers in the province. What then are their options?

The limited opportunities for upward mobility through promotion and permanent appointment, together with the recently negotiated phasing out of automatic salary increases for teachers and revisions

[4] These statistics are limited to 'unqualified' teachers. The number could increase if some qualified teachers also held temporary posts. The statistics are used cautiously since Reddy and Khumalo (1997) only examined statistics for physical science teachers. The two studies are cited because they underestimate rather than overestimate the number of temporary teachers.

in salary scales after completion of a further degree or diploma, may have settled, once and for all, the long standing debate on the class location of teachers in South Africa. An earlier study of teachers and politics also explored this debate *vis-a-vis* coloured teachers in the former HoR schools (Soobrayan, 1992). Hyslop suggested as early as 1987 and Soobrayan concurred, that teachers' work was sufficiently distinct from that of the working class to enable them to place more value on strategies such as 'professionalism' and 'individual upward mobility' for advancing their interests (Hyslop, 1987; Soobrayan, 1992).

Recent labour relations agreements between teachers' organisations and the national Department of Education (DoE) and other initiatives by the Department have increasingly nudged teachers into adopting a proletarian stance so that they are becoming more closely aligned with the working class. The exact nature and implications of this are an issue for further study. Our findings on another related question may also cast light on this. Teachers were asked to comment on a number of characteristics that define a good science teacher. The majority (84%) thought it was important to 'fight for better conditions of service' (42% important and 42% very important).

Although not a direct indication of the shift towards working class/unionist strategies for the advancement of teachers' interests, these findings do suggest a definite rise in working class consciousness among a group that was, until a few years ago, thought to be distinct from and possibly hostile to working class interests.

2.3 Grade level at which educators teach

When separate junior and senior secondary schools were combined into what became known as secondary or high schools, teachers inherited a much broader job description in terms of the grade levels they were expected to teach. Built into their college

preparation was the competence to teach at both the junior and senior levels. Given this assumed competence, schools have adopted different policies with regard to deploying teachers at both junior and senior levels.

The sample revealed that respondents taught general and further education level science, i.e. grades 8 -12. Some of the teachers were engaged at both levels. For example, some teachers taught both grades 9 and 11, while others taught both grades 8 and 11, or grades 8 and 12 or grades 9 and 12.

Table 3: Percentage of teachers deployed in some junior and senior classes (viz. grades 8, 9, 11, & 12)

Grade Level Taught	11	12
8	15%	15%
9	20%	24%

In the two examples presented in Table 3, there was a pattern of deployment at both levels among the white teachers, more often than in the other groups. For instance, 64% of the white teachers taught both grades 8 and 12, compared to 0% for the Indian teachers (and a low average of 15% for all groups combined). Similarly, for grades 9 and 11, 46% of white teachers were deployed compared to 0% for the Indian teachers and 9% for African teachers. Deployment at both junior and senior levels was also higher among the coloured teachers.

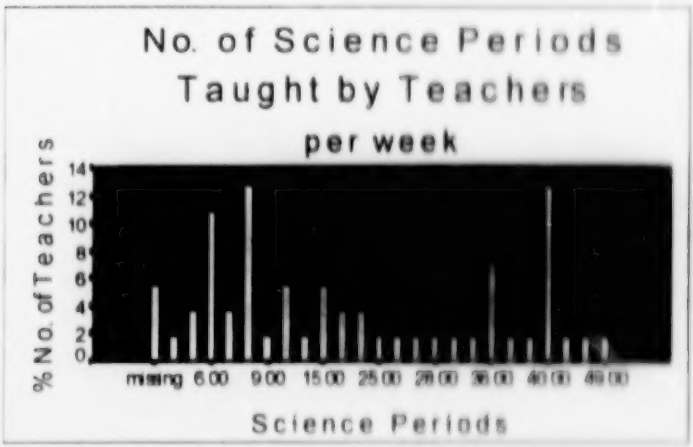
The reasons for these patterns and disparities are unclear. They may be linked to staffing of the different schools, duty allocations, teaching preferences, and perhaps the history of the particular schools that made up the sample. They do, however, have serious implications for the implementation of the Curriculum 2005 programme. As currently conceived, implementation of the new curriculum will occur in phases with two different grades introduced each year from 1999. For example grades 2, 7 and

perhaps 8 will be implemented in 1999 (DoE, 1997b). Thus, at various points during the phased implementation some teachers will have 'one foot in the new world and another in the old world'. For example, in 1999 a teacher who is deployed to teach grades 8 and 12 will teach the new grade 8 curriculum with outcomes-based assessment practices, whilst simultaneously continuing with the old grade 12 syllabus and assessment practices (geared towards a matric examination). This may confuse teachers and lead to uneven teaching practices detrimental to the learners.

Our findings also suggest a need to re-examine current approaches to staff development that pull teachers out of their classrooms to attend workshops. When this happens to a teacher who has commitments to both grade 8 and grade 12 learners, the grade 12 classes may suffer more immediately, although in the long run another group of school leavers will reap the benefits of the teacher's in-service training.

2.4 Science teaching load per week per teacher

The distribution of teaching responsibility in terms of the number of periods taught by each teacher per week was as follows:



Science teachers in the sample indicated that they teach between 4 and 49 periods per week. The wide range of these results makes interpretation difficult and this is further compounded by other factors:

- Differences in the duration of a period. In some schools, a period is 50 minutes, whereas in others it is 35 minutes or 60 minutes.
- Differences in the conception of periods per week. Some schools use the five day calendar (Monday - Friday) whilst others use a 6, 7, or 8 day cycle as their organising frame.
- No clarity on total number of periods per school. Given the different organising frames at the different schools, we expected the total number of periods to vary accordingly.
- Misunderstanding the question. It was clear that some of the responses were providing the number of periods per day as opposed to number of periods per week.

Accordingly we remain uncertain about the relative teaching loads that science teachers carry in the different teaching contexts.

2.5 Deployment to teach subjects other than science

Questions about teacher deployment sought to investigate whether teachers are dedicated to only teaching science. The findings were that dedicated science teaching occurred to significant degrees in all schools except in those schools formerly for African learners only. For example, 91% of the white teachers reported teaching only science compared to only 48% of the African teachers. The figures were also significantly higher for coloured and Indian teachers, 75% and 64% respectively. Most of the African teachers were deployed in two or more subject departments of the school. For instance, 44% also teach mathematics and 37% social studies.

Staff shortages are the most likely variable to explain this situation. However, a broad subject combination in the specialisation of aspirant teachers when training may also be the cause. Although not bad in itself, the latter has implications for the transformation of science education. When teachers are required to change their thinking and practices as demanded by the new curriculum, it is likely to be more difficult for a teacher to devote time, energy, focus and commitment in two or three different learning areas. At such times, dedicated science teaching presents advantages for the teacher.

In a case study of the reform of classroom teaching in the United States, Spillane (1996) demonstrated the challenge experienced by primary school teachers who attempted to change their practices in more than one subject area. Spillane documented and explored the gulf between one teacher's language and literacy lessons that were ambitious and creative, relative to her mathematics lessons that remained traditional. To explain the disparities, Spillane provides two levels of arguments:

- Depth of knowledge in the two learning areas.
  Numerous researchers have shown that subject matter knowledge is critical in enabling a teacher to teach in more creative and non-traditional ways.
- Personal resources.
  Spillane posits that the personal resources such as confidence, disposition and commitment that a teacher brings to learning about new ways of teaching also make a difference.

Dedicated science teaching is more likely to provide teachers with the opportunity to accumulate such personal resources than if they were spreading their efforts across two or three different learning areas.

Grossman and Stodolsky (1995) emphasise the importance of designing policies which are sensitive to what they call 'subject sub-cultures' operating in secondary schools. The basis of their argument is that different subjects give rise to different sub-cultures that are characterised by differing beliefs, norms and practices that affect the teacher's work and responses to reform efforts.

2.6 Class sizes

One of the least problematic issues for the respondents in this sample was that of class size. In general, science classes are less crowded than those for other learning areas and there is an average class size of between 0-27 girls per class and 9-42 boys per class. Slightly less than 2% of the teachers reported classes with numbers of up to 42 boys. It is significant to note that the largest number of girls (27) was way below the largest number of boys (42), suggesting that in some classes, boys far outnumber girls. In the face of decades of research evidence that suggests that science education is more attractive to boys than to girls, the participation of girls in the science classroom needs to come under scrutiny [5]

Science class sizes are generally lower than for other learning areas primarily because of the pre-selection procedures at most schools. Only students whose performance is good are encouraged to do science. Self-selection by students who feel inadequate also limits numbers.

3. Teachers' knowledge

Knowledge is crucial to the success of the transformation project in this country. However, Luis Crouch, 1997, draws attention to the lop-sided emphasis on 'things' rather than the 'redistribution of

[5] However, the findings about the number of boys and girls cannot be generalised to conclude that more boys than girls do science. Recent analysis of educational statistics suggests the reverse (Arnott et al, 1997).

knowledge and ideas' that must underpin South Africa's development.

The importance of the teacher's subject knowledge for classroom transformation has been the subject of a number of research papers, with projects especially concentrated in the United States of America (see Ball, 1995; Ball et al, 1994, 1995; Cohen and Ball, 1990; Spillane, 1996). Much of this research is beginning to push beyond acquired knowledge to examine teachers' opportunities to learn and use new knowledge of teaching (Cohen and Barnes, 1993; Elmore and Fuhrman, 1995; Jennings and Spillane, 1997). Opportunities to learn, where available, provide a critical resource for transforming teaching and learning. In the current project we explore several variables that provide teachers with access to knowledge:

- Academic grounding in the subject.
- Familiarity with the new curriculum framework documents.
- Opportunities to interact with colleagues on the subject matter of science and the new curriculum reforms i.e. opportunities to learn from and with others.

3.1 Academic grounding of science teachers

Of the African teachers who teach only science (i.e. 48% of the sample of African teachers) only 24% had one or more degrees plus a teaching certificate, compared to 63% of white teachers and 54% of Indian teachers.[6] Based on these findings, there may be significant subject matter knowledge disparities between teachers, initiated by apartheid race classifications that afforded them certain learning opportunities. Within this context, white teachers are more likely to be well grounded in the subject matter of science than their counterparts from other ex-departments and African teachers are less likely to be prepared adequately in terms of subject matter.

[6] Data for coloured teachers was inconclusive.

If true, this raises questions about current programmes to develop teachers' capacities to implement Curriculum 2005. The 'one size fits all' approach that provides all teachers with the same tools irrespective of their different starting points is unlikely to do justice to the situation.

3.2 Familiarity with curriculum documents

In August 1995, the national DoE established a Consultative Forum on Curriculum (CFC) to develop frameworks for transforming curriculum in schools. By December, the CFC had released its first discussion document entitled: *Curriculum frameworks for general and further education and training*. The frameworks were followed by a less technical version written as a brochure for advocacy entitled: *Curriculum 2005: a lifelong learning for the 21st century* (also called the Blue Book). In 1997, Learning Area Committee (LAC) reports and further technical reports from smaller committees of learning area experts were developed to translate the goals and outcomes of earlier documents more specifically.[7]

In an attempt to understand the knowledge resources that science teachers bring to the transformation process, teachers in the sample were asked about their familiarity with these reform documents. The responses appear in tables 4 - 7 below.

[7] For a detailed account of such curriculum development processes see Seleti (1997).

Table 4: Familiarity with *Curriculum Frameworks for General & Further Education & Training*

Teachers by race	Never heard of it or not familiar with it	Fairly familiar	Very familiar
Average	26 + 35 = 61%	27%	11%
African	30 + 26 = 56%	7%	33%
Coloured	25 + 25 = 50%	25%	25%
Indian	36 + 9 = 45%	27%	27%
White	46 + 36 = 82%	18%	0%

With the exception of Indian teachers, the majority of science teachers had either never heard of, or were not familiar with this foundational document that heralded the public discussion of curriculum transformation in South Africa. It is perhaps significant that the large majority (82%) of white teachers had never heard of, or were not familiar with the document. Since the processes that led to the development of this foundational document began in 1995 when the former segregated departments were still functioning as administrative agencies, the relative familiarity of Indian teachers with this document suggests that the ex-HoD had effective organisation and communication systems.

Table 5: Familiarity with *Curriculum 2005: lifelong learning for the 21st century*

Teachers by race	Never heard of it or not familiar with it	Fairly familiar	Very familiar
Average	16 + 26 = 42%	47%	9%
African	22 + 19 = 41%	44%	11%
Coloured	50%	50%	0%
Indian	09 + 27 = 36%	55%	9%
White	18 + 36 = 54%	36%	9%

The rather more public document, the 'Blue Book', was still not accessible to the majority of white and coloured teachers. There

was a slight improvement in the accessibility of this document to the African and Indian teachers. However, the gains made among other groups of teachers correspond with a decline among the number of Indian teachers.

Table 6: Familiarity with LAC reports

Teachers by race	Never heard of it or not familiar with it	Fairly familiar	Very familiar
Average	38 + 35 = 73%	16%	6%
African	41 + 22 = 63%	22%	4%
Coloured	25 + 50 = 75%	25%	0%
Indian	27 + 36 = 63%	18%	18%
White	46 + 55 = 100%	0%	0%

Teachers were even less familiar with the LAC reports than they were with the framework documents. Considering that LAC reports represent the penultimate stage in the process of generating a curriculum document that each teacher uses in the classroom, these findings should be a cause for concern among policymakers. Also, considering that LACs represented democratic curriculum policymaking with stakeholder participation at national and provincial levels, these findings are surprising and suggest poor communication flow between teacher organisation representatives and their members and between the DoE and its employees.

Table 7: Familiarity with the Technical Reports for the Natural Sciences

Teachers by race	Never heard of it or not familiar with it	Fairly familiar	Very familiar
Average	47 + 38 = 85%	11%	2%
African	52 + 26 = 78%	19%	0%
Coloured	50 + 50 = 100%	0%	0%
Indian	46 + 36 = 82%	9%	9%
White	36 + 64 = 100%	0%	0%

Responses about familiarity with the technical reports follow the pattern found for the other curriculum documents in the reform process. The technical reports were produced by experts as guides for teachers in transforming their classrooms. These were bound and passed off as the draft national policy statement on the national curriculum for grades 1-9 (DoE, 1997a).

Taken together, tables 4 - 7 suggest that the majority of teachers in this sample appear to have had no/little engagement with curriculum development processes. The reasons for this are not clear. Other researchers and institutions have suggested a number of reasons for the flawed participative processes of curriculum development:

- The problematic nature of the tight timeframes for developing the new curriculum.
- Teachers' lack of experience with curriculum development processes.
- The absence of formal departmental structures for disseminating information and documents to stakeholders, especially teachers.
- Over reliance on experts to drive processes.
- Lack of clarity on about the outcomes-based education and training (OBET) system is and how it might be implemented in a classroom situation (Moodie, 1996; Seleti, 1997).

A combination of factors, including those listed above, probably explains the problems much better than any one factor. Corrective action to engage teachers will have to be initiated if the curriculum is to survive in the classroom. While all teachers should be targeted, the results of this study suggest that the problem is more acute among white teachers. Given the personal resources that white teachers bring to the processes (as mentioned earlier), a likely explanation, is that the near total absence of white teachers

from curriculum processes might have a political rather than procedural dimension.

An emergent hypothesis that requires further testing is that most white teachers have deliberately shut themselves out of transformative curriculum development processes. Discussions with two white teachers selected for the qualitative part of the study did not support this hypothesis. The teachers were as enthusiastic about curriculum transformation as their colleagues in African schools.

3.3 Opportunities to learn with and from others

The survey investigated attendance at national, provincial and local meetings and participation in discussions. More than 72% of the total sample had not participated in national level meetings dealing with science education in the previous year.[8] This applied equally to male and female teachers, although there were more male non-participants than female (91% 78%). Participation levels improved significantly at provincial level, with 63% of white teachers and 46% of African and Indian teachers actively participating. Again, more women (59%) than men (32%) participated.

While the participation levels of African and Indian teachers were 41% and 45% respectively for the local discussion groups or science study groups, participation of white teachers at this level took a big dip to 27%, indicating a lesser preference for engaging in local teacher discussion groups. These patterns may provide clues to ways of conducting learning sessions and professional development that will appeal to different teachers. In general, the data shows that opportunities for teachers to meet with and learn from others arise so infrequently that their contribution to teachers' knowledge is insignificant.

[8] Information from the coloured teachers was incomplete and has thus been left out.

4. Use of textual materials

Drawing on other studies that have already established the disparities and shortages of textual materials, this study focused only on teachers' use of textual materials, including experience as a form of text. The use of five different kinds of texts in different teaching activities was explored. These texts are:

- Teachers' experience;
- Textbooks;
- Syllabuses;
- Past examination papers; and
- Study guides and library books.

Our first concern was how teachers decide on topics to teach. It is not surprising that 78% of teachers rely on the government provided syllabus document for this. In a national education system with a final matriculation examination at the end of grade 12 (and other tests in between), a syllabus document that spells out clearly what the expectations are for each teacher (and learner) is bound to be influential. Relative to all other resources, therefore, when the goal is to provide guidance on topics that should be taught in schools, for the current curriculum, a carefully constructed syllabus document is the best tool policymakers have.

Once selected, the presentation of topics is influenced less by the syllabus and more by a teacher's own experience. On average, 69% of teachers rely on their experiences to present topics in the classroom. However, slightly less than half of white teachers, rely on their experiences. It is not clear what other resources the rest of the white teachers employ as only 9% reported other means (specifically examinations papers and study guides). Thus the nature and quality of teachers' experiences thus play a major role in shaping the quality of

teaching that students are exposed to. High quality teacher education programmes and in-service courses for teachers to broaden their experience and vision of teaching and learning, would go a long way towards facilitating transformation in schools.

Assessment is as important to teachers as presenting the curriculum. On this issue, 72% of teachers use textbooks, previous examination papers and study guides to select problems and exercises for classroom assessment, while 62% use the same resources to select problems for other assessments and evaluation purposes. Very few teachers use their own experience to design assessment tools - the highest being 18% of Indian teachers. Regarding the construction of class work assessment, none of the teachers report using their own experience. The importance of well-written and appropriate textbooks, study guides and samples of examination questions cannot be over-emphasised. Placing poorly designed resources like these in the hands of teachers is a sure way to delay the transformation of science education in schools.

A sad commentary on the results is the finding that none of the African and coloured teachers use library resources for ideas on topic presentations and constructing problems for assessment and evaluation and that only 2% and 4% of Indian and white teachers respectively, use library resources for this purpose. This is despite the finding that 97% of the teachers sometimes use texts other than those prescribed for students. Poor access to libraries may account for this low average use of library books. This is supported by the finding of the *School register of needs survey* that only 30% of secondary schools in KwaZulu-Natal have libraries (DoE, 1997c).

CLASSROOM PRACTICES AS POTENTIAL RESOURCES FOR TRANSFORMATION

A persistent question in policy research has always been the need to explain variations in the way practitioners implement policy. Several scholars have suggested that how policies are implemented and perceived is shaped by practitioners' existing beliefs and capacities (Cohen, March, and Olsen, 1972; Jennings and Spillane, 1997; Keisler and Sproull, 1982; Kingdon, 1984; McLaughlin, 1987; Weiss and Cohen, 1991). Following this argument, South African teachers' beliefs about science and science education and their skills and knowledge can be expected to shape their interpretation of the new science curriculum policies.

1. Teachers' beliefs about science

In the survey questionnaire, two statements of belief contained in the new science curriculum documents were explored. Teachers were asked to voice agreement or disagreement with the following statements:

- Science is an abstract subject.
- Science is the same in all cultures.

Fifty six percent of the teachers disagreed with the statement that science is an abstract subject. They perceived science to be within the realms of concrete and real life experiences. Believing that science is real and concrete represents a good starting point for transforming the current theoretically oriented science education programme in schools. It is worth noting though, that while the majority of coloured, Indian and white teachers strongly disagreed with the statement (100%, 63% and 73% respectively), about 44% of African teachers agreed with it. For policy implementation, this is a significant

variation. An explanation for this may be that most African teachers experienced science education under conditions of extreme poverty and deprivation, often with no laboratories and facilities to make concrete the representations of scientific phenomena. It is conceivable that they have had to approach science from a theoretical standpoint, discussing and imagining what their colleagues elsewhere create and manipulate concretely. Changing teachers' beliefs is not a matter of telling them what they should say (or what their colleagues elsewhere say), but of providing opportunities to experience science differently. Without such opportunities it may be unrealistic to expect teachers to have a different conceptualisation of science and for them to teach their students in a different way.

Regarding the second statement, that science is the same in all cultures, about half of the respondents agreed (42% agreed and 7% strongly agreed). Again, African teachers were the majority (55%) in this group, whilst most teachers from other racial groups disagreed with the statement. The significance of this finding relates to one of the specific outcomes in the new science curriculum which seeks to dispel the myth that science is a neutral discipline and not influenced by culture. This identifies a second weak conceptual area among teachers with repercussions for the teaching of science. Although the origins of this problem are beyond the scope of this study, it can be argued that it points to both an apartheid and colonial legacy of the mis-education of Africans that displaced African people from their culture and heritage.

2. Skills and knowledge that are valued most

Teachers were asked to select which skills and knowledge they valued most in students from the following:

- Understanding of concepts and principles
- Ability to remember formulae and procedures

- Understanding of the relationship between science and culture
- Understanding of the contested nature of science
- Understanding of the interaction between science and socio-economic development

They were also asked whether they agreed with the statement that:

- Focusing on rules is a bad idea

To all but the last statement, teachers' responses were almost unanimous (90% or more) on the importance of these skills and knowledge for science education. Sixty four percent agreed with the statement that disapproves of focusing on rules.

Hidden within this unanimity are contradictions. Firstly, it is not clear how teachers' interpret the statement about 'remembering formulae and procedures' if they disapprove of 'focusing on rules'. One would expect a similar response to the two statements since both relate to a classroom practice that values memorisation and conformity over other ways of learning. A possible explanation for this apparent contradiction may be found in the teachers' concerns about student performance in examinations. Traditional methods of assessing student learning tend to over-emphasise memory work.

Secondly, on the issue of the relationship between science and culture, 78% of African teachers felt that culture was very important to the content of science education, while only 27% of white teachers were equally enthusiastic. Another 27% of the white teachers regarded such content as unimportant. Again, these findings seem to contradict earlier findings that half the African teachers agreed with the statement that 'science is the same in all cultures'. One possible explanation is that the earlier finding about science being the same in all cultures might have been an 'official response' that avoids

controversy, because then the issue was raised later in the context of worthwhile knowledge to teach, a more considered response emerges.

Thirdly, there was a similar response to the statement about understanding the contested nature of science. Sixty percent of African teachers thought it very important to include this issue in science education, but there was ambivalence among white teachers. Only 27% of white teachers agreed, with another 27% expressing disagreement. There were similar findings on understanding the interaction between science and socio-economic development.

3. Pedagogical approaches

The new vision of scientific literacy encompasses, among others, a functional conception of scientific knowledge that allows citizens to reason through science, to represent their knowledge in different ways, provide explanations and solve problems in real life situations (DoE, 1997a). Most teachers in the sample reported such progressive pedagogical practices in their classrooms. The following were given as characteristic features of most of their lessons:

- **Asking students to explain the reasoning behind their ideas:** 84% of the teachers reported doing this a lot in their classrooms.
- **Asking students to write explanations about what was observed and why it happened:** 55% of all the teachers reported doing this frequently. Significantly however, only 27% of white teachers asked students to write these explanations in most lessons and 9% of white teachers never or almost never demanded this of their students.
- **Asking students to apply concepts and principles to real life problems:** it is encouraging that, overall, 66% of all the teachers frequently demanded this from students. However, a racial analysis of responses indicates that while most African teachers demand

this frequently (78%), less than half the white teachers demand it of their students (45%).

Significantly, more African teachers than teachers from other groups reported these progressive features in most of their lessons. In the current context of the rhetoric about educational disadvantages in African schools, discerning fact from reality can be challenging. The findings suggest that despite the conditions and problems of most schools serving African children, pedagogically speaking they contain features of a progressive pedagogy that is less evident in some of the more privileged white schools. These features of a progressive pedagogy are not measured by or reflected in the matriculation examination results. The matriculation examination measures traditional skills rather than the new learner centred skills. Also, the matriculation examination is not a tool for teacher appraisal but an instrument to determine learner performance.

Attention needs to be drawn again to the fact that these are practices as reported by teachers in a questionnaire protocol. Although there is no reason to doubt what teachers report about themselves in a questionnaire that has no connection with their performance appraisal at the school, research rigor dictates cautious interpretation of this data and that the findings should be verified or disputed through classroom observation.

A few teaching practices were less popular across the board:

- **Asking students to represent and analyse relationships using tables, charts or graphs:** only 40% of all the teachers frequently asked students to do this - 9% of white teachers, 27% of Indian teachers, and 25% of coloured teachers, relative to 59% of African teachers. Although applicable to science, the ability to analyse relationships using tables, graphs or charts is essentially a mathematical skill. Given that in most African schools science teachers were reported to be math teachers as well, the transfer of

mathematical skills to science is not unexpected. The reverse may be true for other groups of teachers in the sample.

- **Asking students to work on problems for which there is no immediately obvious method of solution:** only 20% of the teachers reported doing this in most of their lessons. The breakdown by race for teachers who required this (in most lessons) was as follows:

African teachers	34%
Coloured teachers	25%
Indian teachers	0%
White teachers	9%

In summary, African teachers are more likely to challenge students to do more than solve textbook problems for which the answers or methods of solving are known. South Africa's traditional assessment system tends to reward memorisation over other progressive skills, although recently this has been replaced by a continuous assessment approach that measures diverse processing skills. Nevertheless, it would not be surprising if African and coloured teachers in this sample who were truly engaged in progressive practice were not recognised or rewarded through traditional teacher appraisal processes. Further research into teachers' practice is required to identify aspects of progressive teacher practice that can be nurtured and encouraged. Later activities of this project attempt to take on this challenge.

CONCLUDING REMARKS

In the introduction it was argued that there is a need to reconceptualise the notion of educational resources for transformation. Despite the handicaps created by inadequate provision of material and physical resources, disadvantaged schools are often found to have other invaluable resources for education under these circumstances. They have rich contexts comprising people, knowledge, time and texts, and practitioners have developed a rich repertoire of practices. Other scholars define context variables such as knowledge, human resources, time, and texts as important capacities for transformation. This study proposes a broadening of the notion of 'capacity' to transform schools. Instead of defining capacity only as a resource that is the 'property of the individual' to utilise, it is conceptualised as the potential of the whole school system to reach a maximum level of performance i.e. to reach its optimal capacity.

The study uncovers the huge potential that exists for schools to transform their science education programmes. This potential was described in terms of teachers' knowledge, time available and how time is used in schools, human and textual resources and various teaching practices that feature a transformative engagement. As indicated at various points in the document, the challenge remains that of organising these resources in such a way that they support transformation. This summons attention to the following issues raised in the document:

- **Institutional racism.** Despite the policies of non-racial education, South African schools continue to reflect patterns of previous racial segregation, especially in teacher deployment. In general, white teachers continue to teach at white schools and coloured teachers continue to teach at coloured schools, etc.

- **Experiences of boys and girls in science classrooms.** This study found no evidence of under-representation of female science teachers. There was some evidence of such under-representation in the case of students but these findings were inconclusive. The issue raised by these observations is the need to focus more closely on teaching and learning in classrooms where such configurations occur. This will provide the opportunity to examine whether all students are given an equal opportunity to learn science. Such questions can only be answered through studies that focus on teachers' practices inside the classrooms.
- **Poor prospects for professional advancement of teachers.** Increasingly, teachers' opportunities for upward mobility within the school system have dwindled. Given this reality, teachers are likely to explore other ways of advancing their interests. Increasingly they are turning to working class politics to achieve this, and in doing so are building a strong trade union movement within the sector. The content and politics of this trade union movement will be crucial in the development of the profession as a whole.
- **Deployment of teachers in general and further education levels.** Most teachers teach classes ranging from grade 8 –12. This has implications for the implementation programme of Curriculum 2005, which introduces grades phases. As currently conceived, some teachers are likely to have some of their classes being taught the new curriculum while teaching the old curriculum to another grade.
- **Knowledge as the basis for transformation.** Like Crouch (1997) we subscribe to the view that knowledge should underpin development in South Africa. The finding that most teachers are unfamiliar with curriculum reform documents and processes is cause for concern. This is especially true in the case of white teachers in the sample. Variations in the teachers' beliefs about science and science education result in different understandings of the demands of the new curriculum. This leads to diverse

approaches for implementing the curriculum and may further exacerbate inequalities in schooling.

- **Material resources for transformation.** Most teachers in the sample rely on the syllabus document, textbooks and their own experiences to make instructional decisions. Thus, as important policy levers for change, syllabuses should be carefully and deliberately crafted, textbooks should carry a transformative content, and in-service workshops should broaden teachers' experiences and visions of science teaching and learning. Making teachers more familiar with transformative pedagogical practices is crucial because they can only be expected to teach in ways that are familiar to them.
- **Features of progressive classroom pedagogy.** These were found to exist already in some schools, especially the African schools in this sample. Further work on characterisation of these practices and how they can be nurtured and sustained is needed.

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